Process Evaluation Section

Recycling of Polymer Matrix Composites (PMCs)

Problem/Opportunity

Carbon fiber reinforced polymer matrix composite (PMC) materials are exhibiting such high strength-to-weight ratios that they are finding increasing applications in the aerospace industry. They are also being evaluated as possible construction materials in the automotive industry. The major barriers to their widespread use is their high cost and concerns about whether they are going to be recyclable when the vehicles reach the end of their useful lives. With funding provided by the Department of Energy's Office of Advanced Transportation Technologies, Argonne is developing an efficient and cost-effective process to recover the high-valued carbon fibers.

Approach

The technical approach to process development consisted of 4 major stages. They are:

(1) Investigate and bench-scale test the potential methods for liberating the carbon fibers from the polymeric substrate. Three processes were investigated: thermal treatment, chemical treatment, and thermal shock. We also evaluated hybrid methods (thermal followed by chemical, chemical followed by thermal, and thermal treatment followed by ultrasonic separation).
(2) Test the most advantageous method at a larger scale and analyse its economics.
(3) Work with a carbon fiber manufacturer to produce and test PMC panels made with recovered fibers and compare their properties with similar virgin-fiber panels in order to establish the quality of the recovered fibers.
(4) Recover carbon fibers for re-use in an automotive application.

Results

Research done so far has resulted in the following accomplishments:

- The thermal treatment method, a single-step process, recovered carbon fibers from PMC scrap with a minimal loss of the carbon fibers, see Figures 1,2.
- The process has a potential payback period of less than 2 years. Therefore, its development toward commercialization is continuing.
- We recovered fibers from PMC panels that were supplied by Hexcel Carbon Fibers, Inc., and were made with known fibers and known substrates. The recovered fibers were evaluated by Hexcel and by ORNL. The recovered fibers:
  - Had high shear strength and high O_2 on the fiber surfaces which indicate that the recovered fibers should adhere well to matrix resins without the need for additional surface treatment. This will save about \$0.40/lb. of fibers. Surprisingly, some of the recovered carbon fibers exhibited higher levels of elemental oxygen at and just beneath the fiber surface than do the corresponding virgin fibers.
  - Within experimental error, the physical and morphological characteristics of the recovered fibers are identical to those of the virgin fibers. See Table 1 and Figure 3.

Hexcel used the recovered carbon fibers to make new PMC panels of equivalent dimensions and compared the properties of these panels to the original PMC panels from which the fibers were recovered. The data showed ~ 10% reduction in

stiffness and ~ 12% reduction in the short beam strength. The new PMC panels also had ~50% reduction in strength and elongation. These results demonstrate that the recovered fibers are suitable for use in chopped fiber applications.

A continuous thermal reactor capable of treating 5 kilograms per hour (kg/h) of PMC material has also been designed, built and tested.

In summary, work conducted so far has demonstrated that the recovery of carbon fibers from PMC scrap is technically feasible and potentially economical. The recovered fibers have properties that make them usable in chopped fiber applications for making value-added products such as car, fuel cell, and battery parts.

Future Plans

To prove the quality of the recovered fibers, we plan to recover enough carbon fibers to use in manufacturing skid plates for sport utility vehicles using the Budd Slurry Process.

We also plan to demonstrate this technology at an industrial site, and we plan to develop a process to recover expensive thermoplastics used in PMCs, instead of thermally degrading them.

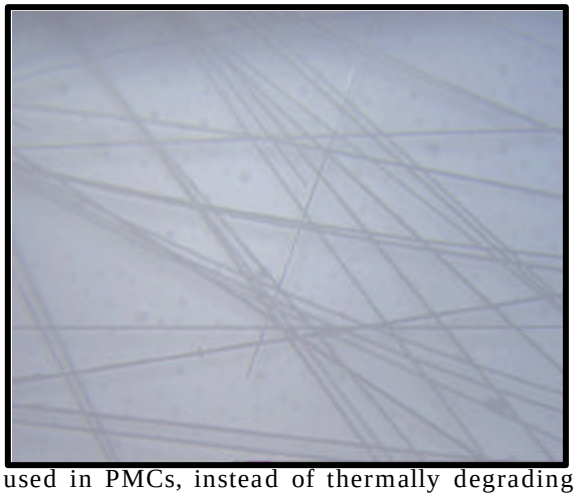

Figure 1. A picture of magnified carbon fibers taken under a microscope.

Figure 2. A typical PMC panel before thermal treatment (left) and the recovered carbon fibers after treatment (right).

Table 1. Comparison of the density and diameter of the recovered carbon fibers with virgin carbon fibers

Sample	Density (g/cc)	Diameter (μm)
Virgin	1.8553	5.33
Recovered	1.8561	5.39

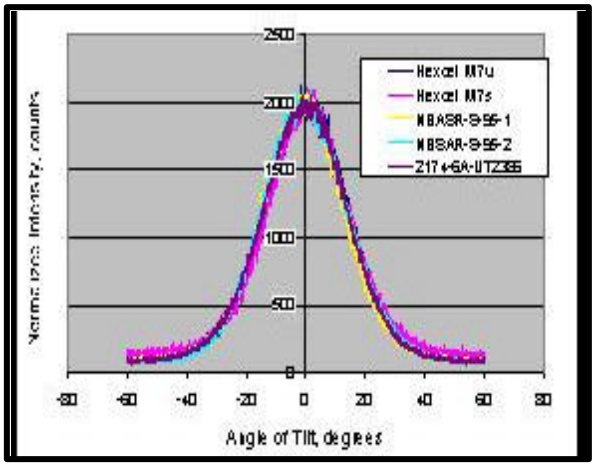

Figure 3. Azimuthal scans of the 002 reflection of virgin and recycled carbon fibers showing the orientation of the graphene planes. All curves superimpose.